UNIVERSITI PUTRA MALAYSIA

GROWTH AND PHOTOSYNTHETIC EFFICIENCY OF ACACIA MANGIUM WILLD AND ACACIA AULACOCARPA A. CUNN EX, BENTH MULTIPLE LEADERED TREES

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By

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GROWTH AND PHOTOSYNTHETIC EFFICIENCY OF *Acacia mangium* WILLD AND *Acacia aulacocarpa* A. CUNN EX. BENTH MULTIPLE LEADERED TREES

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Chairman: Professor Nor Aini Ab. Shukor, PhD

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Acacia mangium Willd. and *Acacia aulacocarpa* A. Cunn. Ex. Benth are among the two important *Acacias* planted in Malaysia and both species exhibited multiple-leader (ML). ML is the formation of more than one stems from the base of planted trees which affect the productivity of the stands if they are to be used for timber production. With more volume of wood per tree basis, ML trees were considered as an advantage for pulp and paper industry. However, its productivity and wood quality are still being questionable to the industry. Thus, this study was conducted to evaluate the growth performance after seven years, aboveground biomass (AGB), specific gravity of wood (SG_{wood}) and photosynthetic efficiency of ML trees of these species.

Growth performance of seven-year old trees was based on diameter at breast height (Dbh) and height. Then, biomass was estimated from a total of 72 trees (2 species x 4 provenances x 3 Dbh classes x 3 replicates. Specific gravity of wood (SG_{wood}) was then estimated using similar Dbh groupings and also based on three levels of height. In addition, gas exchange was also estimated using similar Dbh groupings between ML and single stemmed trees to establish the light response curve to estimate their maximum rate of photosynthesis (A_{max}) and quantum yield (Φ).

The growth performance at 7 year-old indicated significant differences at $P \leq 0.05$ between species and provenances with regards to Dbh and height. *A. mangium* outperformed *A. aulacocarpa* for both attributes. On the other hand, trees of *A. aulacocarpa* from PNG provenances performed better than the ones from QLD. There were also significant differences at $P \leq 0.05$ between provenance in terms of stem and total biomass and; between Dbh, all parameters of AGB of *A. mangium*. *A. mangium* from SW of Boset WP (PNG) recorded the highest mean of AGB (400.19 kg) and Russel & Gap CK (QLD) recorded the least (202.68 kg). On the other hand, *A. aulacocarpa* showed significant differences between provenances and Dbh classes for all parameters measured with provenance from Arufi E. Morehaed WP (PNG) gave the highest total AGB (219.72 kg) and provenance from 3K S Mt Larcom, QLD recorded the least (34.12 kg). *A. mangium* was better than *A. aulacocarpa* in terms of biomass production. In addition, eight regression equations to estimate aboveground biomass and revealed that Dbh is the main factor affecting the production of the different provenances.

Generally, SG_{wood} of *A. aulacocarpa* was higher than the ones produced by *A. mangium* especially from lower part of trees. There was also significant difference between height levels with regards to provenance and Dbh classes. Generally, the order of SG_{wood} production for both species is bottom> middle> top. Moreover, there was no significant difference at $P \leq 0.05$ between provenances, growth habits (ML and SS), Dbh classes and their interaction in terms of A_{max}. Similar statistical analyses were also obtained for quantum yield except for between provenances of *A. mangium*.

Based on composite ranking of all attributes revealed that *A. mangium* from SW of Boset (PNG), Captain Billy Road (QLD) and Bensbach WP (PNG) and *A. aulacocarpa* from Arufi E. Morehaed WP (PNG) and W. Morehead (PNG) showed relatively good performance and indicated their suitability and robustness to local environment. The results also revealed that growth performance was positively correlated with AGB but not for SG_{wood}, A_{max} and quantum yield between species and provenances. Thus, the above potential provenances should be considered in breeding programme of *Acacia* species for the purpose of high yield productivity.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi syarat keperluan untuk ijazah Master Sains

TUMBESARAN DAN KECEKAPAN FOTOSINTESIS POKOK PELBAGAI CABANG *Acacia mangium* WILLD DAN *Acacia aulacocarpa* A. CUNN EX. BENTH

Oleh

SAPARI BIN MAT

Januari 2008

Pengerusi: **Professor Nor Aini Ab. Shukor, PhD**

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Acacia mangium Willd. dan *Acacia aulacocarpa* A. Cunn Ex. Benth adalah dua daripada kalangan spesis Akasia yang penting yang di tanam di Malaysia dan kedua-dua spesis menunjukan kecenderungan menghasilkan cabangan pelbagai (ML). ML ialah percabangan bermula daripada pangkal pokok yang mempengaruhi produktiviti dirian tersebut jika penggunaannya adalah untuk penghasilan kayu gergaji. Ia menghasilkan isipadu kayu yang lebih banyak untuk satu dirian, dan merupakan satu kelebihan kepada industi pulpa dan kertas. Walaupun begitu, produktiviti dan kualiti kayu masih lagi menjadi tanda tanya untuk pihak industri. Maka, kajian ini dijalankan untuk menilai prestasi pertumbuhan pada dirian tujuh tahun, biojisim dirian atas tanah (AGB), ketumpatan bandingan kayu (SG_{wood}), dan kecekapan fotosintesis pokok pelbagai cabang.

Prestasi pertumbuhan adalah berdasarkan kepada diameter pada paras dada (Dbh) dan ketinggian pokok. Manakala, biojisim dianggarkan menggunakan 72 pokok (2 spesis x 4 provenan x 3 kelas Dbh x 3 replikasi). Ketumpatan bandingan kayu (SG_{wood}) di tentukan menggunakan pengelasan Dbh yang sama pada tiga paras ketinggian yang berbeza. Selain daripada itu, pertukaran gas juga dianggarkan menggunakan pengelasan Dbh yang sama di antara pokok pelbagai cabang dan pokok satu cabang untuk menghasilkan lengkung tindakbalas cahaya bagi menentukan kadar maksimum fotosintesis (A_{max}) dan hasil kuanta (Φ) masing-masing.

Prestasi pertumbuhan dirian pada umur 7 tahun menunjukkan perbezaan yang bererti pada tahap $P \leq 0.05$ di antara spesis dan provenan berdasarkan Dbh dan ketinggian pokok. *A. mangium* berprestasi lebih baik daripada *A. aulacocarpa* untuk kedua-dua ciri pertumbuhan tersebut. Manakala, provenan *A. aulacocarpa* daripada rantau PNG menunjukkan prestasi yang lebih baik daripada provenan QLD. Terdapat perbezaan yang bererti pada $P \leq 0.05$ di antara provenan dan di antara Dbh berdasarkan nilai biojisim batang, jumlah keseluruhan biojisim dan semua parameter AGB untuk *A. mangium*. *A. mangium* daripada SW of Boset WP (PNG) merekodkan purata tertinggi pada biojisim atas tanah (400.09 kg) dan Russel & Gap CK (QLD) merekodkan purata terkecil (202.68 kg). *A. aulacocarpa* sebaliknya menunjukkan perbezaan yang bererti di antara provenan dan kelas Dbh untuk semua parameter di mana provenan daripada Arufi E. Morehead WP (PNG) memberikan putara biojisim atas tanah yang tertinggi (219.72 kg) dan provenan 3K S Mt Larcom (QLD) mencatatkan bacaan terendah (34.12 kg). Di samping itu juga lapan persamaan regresi untuk menentukan biojisim di atas

tanah telah di hasilkan dan menunjukkan bahawa Dbh merupakan faktor utama dalam menentukan penghasilan biojisim diatas tanah pada provenan yang berbeza.

Secara amnya, ketumpatan bandingan untuk *A. aulacocarpa* adalah lebih tinggi daripada *A. mangium* terutamanya di bahagian paras bawah pokok. Terdapat perbezaan yang beerti diantara tinggi paras pokok dengan merujuk kepada provenan dan juga kelas Dbh. Secaranya amnya, urutan penghasilan ketumpatan bandingan bagi kedua-dua spesis adalah seperti berikut: bawah> tengah> atas. Lanjutan daripada itu, terdapat perbezaan yang tidak bererti pada tahap $P \leq 0.05$ di antara provenan, ciri pertumbuhan (pelbagai cabang dan dirian tunggal), kelas Dbh dan interaksi antara parameter untuk nilai fotosintesis maksima (A_{max}). Analisa statistik sama juga didapati untuk hasil quanta kecuali di antara provenan *A. mangium*.

Berdasarkan kepada pengelasan keseluruhan yang melibatkan pelbagai ciri, provenan SW of Boset (PNG), Captain Billy Road (QLD) dan Bensbah WP (PNG) untuk *A. mangium* dan provenan Arufi E. Morehead WP (PNG) dan W. Morehead (PNG) untuk *A. aulacocarpa* adalah dikalangan genotip yang menunjukkan prestasi yang terbaik dan mengesahkan kesesuaian mereka terhadap persekitaran tempatan. Kesimpulan kajian ini menunjukkan ciri pertumbuhan memberi kesan positif ke atas biojisim tetapi tidak untuk ketumpatan bandingan kayu, nilai fotosintesis maksima dan hasil kuanta di antara spesis dan provenan. Maka, provenan di atas yang menunjukkan potensi harus di pertimbangkan di dalam program pembaikbiakan Akasia yang memberi penghasilan tinggi.

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I dedicate this thesis to my beloved mother…

I certify that an Examination Committee has met on 9th January 2008 to conduct the final examination of Sapari bin Mat on his Master of Science thesis entitled "Growth and Photosynthetic Efficiency of *Acacia mangium* Willd and *Acacia aulacocarpa* A. Cunn ex. Benth Multiple Leadered Trees" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the student be awarded the degree of Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Date: 10th April 2008

DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

SAPARI BIN MAT

Date: 1st April 2008

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LIST OF ABBREVIATIONS

AGB	Aboveground Biomass
A_{max}	Maximum Rate of Photosynthesis
ANOVA	Analysis of Variance
ATP	Adenosine Triphosphate
CFPP	Compensatory Forestry Plantation Project
cm	Centimeter
CR	Composite Ranking
CSIRO	Commonwealth Scientific and Industrial Research Organization
Dbh	Diameter at Breast Height (1.3 m from the ground)
DMRT	Duncan's Multiple Range Test
E	East
FAO	Food and Agriculture Organization
FDPM	Forestry Department of Peninsular Malaysia
ha	Hectares
IBP	International Biological Programme
k	Convexity
kg	Kilogram
m	Meter
MAI	Mean Annual Increment
ML	Multiple-leader
MOSTI	Ministry of Science, Technology and Innovation

Mt.	Mountain
N	North
NADPH	Nicotinamide adenine dinucleotide phosphate
NAS	National Academy of Science
OCR	Overall Composite Ranking
PAR	Photosynthesis Active Radiation
PFE	Permanent Forest Estate
PNG	Papua New Guinea
ppm	Part per Millions
Q	Photon flux
QLD	Queensland
R_{day}	Day Respiration
RubP	Ribulose-1, 5-bisphosphate
SAFODA	Sabah Forestry and Development Authority
SAS	Statistical Analysis System
SG_{wood}	Specific gravity of wood
SPSS	Statistical Package for Social Science
SS	Single Stem
subg.	Sub Genus
syn.	Synonym
UPM	Universiti Putra Malaysia
W	West
WP	West Provenance

Φ	Quantum Yield
RELP	Restriction Fragment Length Polymorphism

CHAPTER 1

INTRODUCTION

1.0 Background of the Study

Forest plays an important role in the socio-economic and industrial development in Malaysia. It contributes significantly in maintaining environmental stability including the protection of water resources, biological diversity and the flora and fauna. These roles of the forest must be maintained and perpetuated not only for the benefits of the present but also for the future generations. Besides its richness of biodiversity, timber industry remained one of the main contributors of our national wealth and it is estimated that there also provided employment of about 2 percent of the country's labour force (Mohd Shahwahid, 2004).

A report by the Malaysian Institute of Economic Research (MIER) noted that the supply shortage of wood was predicted to become serious in 2012. Furthermore, Malaysia's furniture export value could potentially rise to RM12 billion in 2010 from RM7.7 billion in 2005 (Mohamad Ariff, 2005). With the high demand of wood, the pressure on the natural forests was at an alarming stage. This resulted in the Malaysian government introducing the forest plantation programme. Therefore, fast growing and high yielding tree plantations are becoming important sources of wood in Malaysia. Forest plantation was first introduced in Malaysia in the beginning of the last century when rubber tree

(*Hevea brasililiensis*) which was planted at Kuala Kangsar, Perak for the rubber production. Till then, there are many species from many parts of the world such as *Pinus caribaea*, *Araucaria* spp, *Eucalyptus* spp, *Tectona grandis* as well as the indigenous species i.e. *Dryobalanops aromatica*, *Azadiracta excelsa* and *Shorea macrophylla* (Appanah and Weinland, 1993) have been planted as forest plantations with specific objectives.

The supply of wood was sufficient in 1970's to the years of 80s. However, it has been reported that the supply was insufficient with what was demanded in late 80s where areas of productive forest become scarce. Thus, the Compensatory Forest Plantation Project through a loan from Asian Development Bank was initiated. The aim of that project was to plant fast-growing hardwoods such as *Acacia mangium*, *Gmelina arborea* and *Falcataria moluccana* to produce general utility such as sawlogs and pulp and paper. Eventhough the project was ended, planting *A. mangium* for pulp and paper production continued in Malaysia especially in Sabah (Rahim and Anuar, 1995) and Sarawak (Kendawang, 1996), because of its impressive growth performance in terms of Dbh and height.

With high adaptability to the wide range of soils and climate, *Acacia* species were chosen as the most potential species for forest plantation in Peninsular Malaysia, Sabah and Sarawak. These species were planted throughout Malaysia, and these include some of the lesser known *Acacias* species such as *Acacia aulacocarpa*, *Acacia crassicarpa* and *Acacia auriculiformis*. Hitherto, a progeny trial was established at Kuala Lipis,

Pahang to assess the site adaptability of these species (Ahmad, 2003). Despite being fast-growing and multipurpose, these species have exhibited some problems regarding tree form and growth habit, for the example, multiple-leader formation and heavily branching which possibly affect wood production for specific purpose. *A. mangium* and *A. aulacocarpa* in plantations of Peninsular Malaysia have been reported to form extensive multiple-leaders (Srivastava, 1993 and Ahmad, 2003). Multiple-leader (ML) is a formation of more than one stem/ trunk from the base of planted trees and it is possibly caused by either genetics or environmental factors or even an interaction of them.

As the preferred requirement for harvesting is single stems, singling, i.e. conversion of multi-stemmed to single-stemmed trees is undertaken routinely at around age 4 – 6 months (Weinland and Zuhaidi, 1991). The preferred practice is green pruning that remove live rather than the dead branches. Dead branches are associated with a high percentage of discoloration and decay in unpruned *A. mangium* (Ito and Nanis, 1994. Based on certain objective, ML can be as advantage or disadvantage for the industry. For instance, if the end product is pulp and paper, ML trees can provide greater volume of wood compared to single stemmed trees (Sapari, 2002). Most of the time, wood that been singled not been utilized, if any only as an additive raw material in composite wood manufacturing (Kong, 1998). Thus, an understanding of the physiology relationship with regards to growth performance, photosynthetic efficiency and wood properties of these species is vital to enable productivity to be maximized and sustained, and the biomass produced to be easily harvested and efficiently utilized. To date,

assessment of these were based on early growth performance in terms of Dbh, height and aboveground biomass while there is limited records on gas exchange characteristics available with regards to these species/ provenances.

1.1 The Objectives of the Study

In order to understand the growth attributes and their physiology, this study was conducted with the following objectives. They are:

1. To assess the growth performance, aboveground biomass (AGB), specific gravity of wood (SG_{wood}) and photosynthetic efficiency of *Acacia mangium* and *Acacia aulacocarpa* multiple leadered (ML) provenances

2. To relate the growth performance with regards to AGB, SG_{wood} and photosynthetic efficiency of *Acacia mangium* and *Acacia aulacocarpa* ML provenances

It is envisaged that the information obtained from this study will provide a better understanding of the growth attributes and physiology of *A. mangium* and *A. aulacocarpa* ML trees. Both species are fast growing, with an increasingly important role in the reforestation programmes.